IASDR 2019
International Association of Societies of Design Research Conference 2019
DESIGN REVOLUTIONS
Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

From Fore-thinker to Facilitator: The Role of Design in the 4th Industrial Revolution

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The purpose of this paper is to provide and explain a vision of the changing role of design in the 4th industrial revolution. By looking at the sustainability crisis caused by our previous industrial and economic development through a F-P-N(Forethought-Production-Needs) model, the paper explains the problem that the previous three industrial revolutions tended to solve and the strategies that industrial development adopted, it explains why and how design has played a role as fore-thinker and why the previous industrial paradigm failed to be sustainable. The authors assert that Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the dynamic and constant change of the market, which represents the individual and collective human needs. In such light, the emerging 4th industrial revolution and the role of design are expected to enable the shift of our industry paradigm from “what we manufacture” with the focus of production efficiency and rhetoric strategy of design, to “why we manufacture” with the focus of production effectiveness and dialectic strategy of design. In order to realize such paradigm shift, the paper points out that it is critical to realize that design being as fore-thinker will no longer be helpful enough in a network-based industry. Instead, formations of design cultures throughout all aspects of a networking industry are needed. The knowledge of design should no longer be mastered among the few, but blend into the network of innovation and production communities of the future industry by the facilitator of design culture. The paper concludes that, in the coming 4th industrial revolution, the role of design is not to be discovered nor predicted, but to be shaped through increasing dialectic research and practice to facilitate a more resilient and sustainable future industry and economy.

Keywords: industrial revolution; the role of design; industrial design

1 Introduction

Why do we need another industrial revolution? What the next industrial revolution is expected to realize? One reasonable answer is that it should set out to solve the problems of our existing industry and economy. Otherwise, what is the point if we just accelerate the capacity together with its side effects of our current industry model? The world is not lack of sexy or cool looking automobiles anymore but is longing for innovative approaches to tackle complex sociotechnical problems such as intelligent urban mobility or healthcare, government policy, and environmental protection (Donald A. Norman, 2015). One of the reasons that human society is faced with today’s sustainability crisis is the linear model of

industry in which a product is designed, mass-produced, delivered, sold, used and discarded. This whole production model is based on the “forethought” (Richard Buchanan, 2009) and competition about what the markets or users might want with the available technology environment. The role of design during the past three industrial revolutions is deeply involved at such “forethought” stage.

Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the changing dynamic needs of the market. The previous three industrial revolutions focused on the upgrade of manufacture efficiency through the invention of mechanized production, flow line production and automated production. The result is that more products will be produced more efficiently to be sold and replaced more quickly. However, production growth on our planet fundamentally cannot be infinite due to the limited natural recourse for production. Sustainability crisis caused by existing industry model is becoming more and more serious. With such reality and problems, we assert the emerging 4th industrial revolution and the role of design are expected to enable the shift of our industry paradigm from “what we manufacture” with the focus of production efficiency and rhetoric strategy of design, to “why we manufacture” with the focus of production effectiveness and dialectic strategy of design.

2 The F-P-N Model and the previous industrial revolutions

Industry is defined as the companies and activities involved in the process of producing goods for sale. The purpose of industry production is to meet the needs of people and make better life. It is necessary to make a schedule before production otherwise it is impossible to decide what to produce and how to produce. Therefore, design plays the role of forethink needs before production. From the perspective of time, the whole process can be described as: 1. Design makes **forethought**. 2. Goods are put into **production**. 3. **Needs** get satisfied. (F-P-N model) The three steps are in chronological order and the model is so-called ‘linear model’, in which design is at the front-end of the whole process.

For a long time, industry has been pursuing efficient production to meet people's different needs as well as maximize profits. The prominent events are the previous industrial revolutions. After each revolution, driven by economic factors or interests, industry constantly upgrade technology, thus the efficiency of production is greatly improved, and people's needs are better satisfied.

2.1 The 1st Industrial Revolution

During the 1st industrial revolution, steam-powered mechanized production was invented to replace human-powered manual production, which indicated the arrival of the industrial era in human history. Design and manufacture were closely integrated at that stage. In order to make products accessible to more customers, and to avoid accidents in the mechanized production, it was necessary to plan and coordinate various types of work and processes before mass production and integrate the restrictions and interests from the manufacture side and the market side including manufacture feasibility, assembly and transportation efficiency. Although the technology revolution enabled dramatic production efficiency increase, the users' choices from available products were still limited, and there was a long-time span from the forethought to the market, as shown in Figure 1.

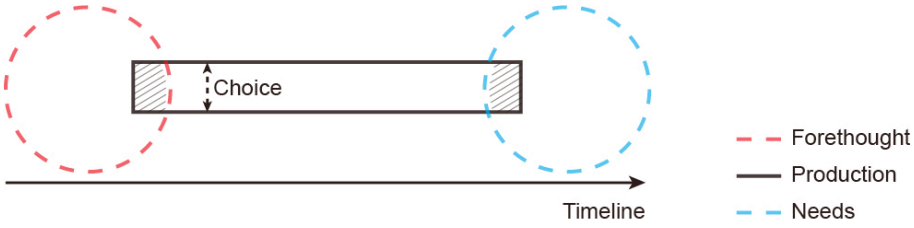

Figure 1. Model during the 1st Industrial Revolution

The Thonet chair, as shown in Figure 2, was a good example of that period. It was partially mechanized production and partially assembled by manual with standardized parts, which can be used in different styles. The design of Thonet 14 is especially suitable for the serialization of production in factories. It is designed into serval simple parts, which is convenient for disassembly, transportation and assembly. It reflects the whole system integration of product design from material processing to production circulation.

Figure 2. Thonet chair No.14. Source: Google

2.2 The 2nd Industrial Revolution

During the 2nd industrial revolution, the flow line production model of production management and organization further improved productivity, and the choice of products increased and the time span between product forethought to delivery was corresponding shorten, as shown in Figure 3. People can choose between different products to meet a certain demand. This drove design to consider the coordination of function with aesthetics and economy, which improved the value and competitiveness of products. At that time, the primary role of design was to plan and forethink mass produced products with increasing consideration on emotional interaction between products and users. The contents of industrial design were also gradually enriched with the pursuit and creation of style and fashion. Design was also recognized as future-oriented and played a role as fore-thinker of new choices.

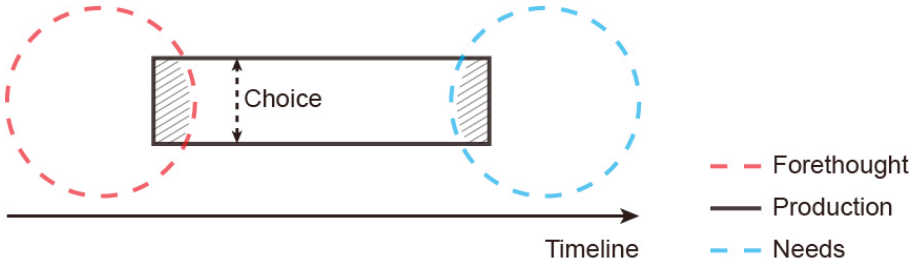

Figure 3. Model during the 2nd industrial revolution

Model T was the first automobile produced through flow line production. The average assembly time of chassis was shortened from 12.5 hours to 1.5 hours. (History of Ford) Flow line production allowed the price of the touring car version to be lowered from $850 in 1908 to less than $300 in 1925. At such prices, the Model T at times comprised as much as 40 percent of all cars sold in the United States. On such basis, Ford designed different body styles of Model T including a five-seat touring car, a two-seat runabout, and a seven-seat town car to meet different needs. Design still playing a role as fore-thinker helped to make products more competitive in the markets. Meanwhile, design is not just about how to adapt to the requirement of high-speed production, but to take consideration of customers' segmentation needs even aesthetic judgement.

Figure 4. Flow line production of Model T. Source: Ford

2.3 The 3rd Industrial Revolution

During the 3rd industrial revolution, the invention of integrated circuit promotes the emergence of automatic production line, which further improved the level of production capacity and efficiency, as shown in Figure 5. The industry entered the era of automated production. During this period, benefit from the breakthrough of production efficiency and accuracy, mass production based industry gained more resilience and began to be able to respond according to customer orders. Consumers could customize products to satisfy personalized needs. The back-end of industry chain began to participate in the decision-making stage which was exclusive to front-end before. Meanwhile, design began to integrate elements of vision and meaning of product experience as well as the establishment of brand image and brand culture. During this period, designers started to play the role of creators and fore-thinkers of product experience. There also started a trend that design gradually became a dominant factor in some companies.

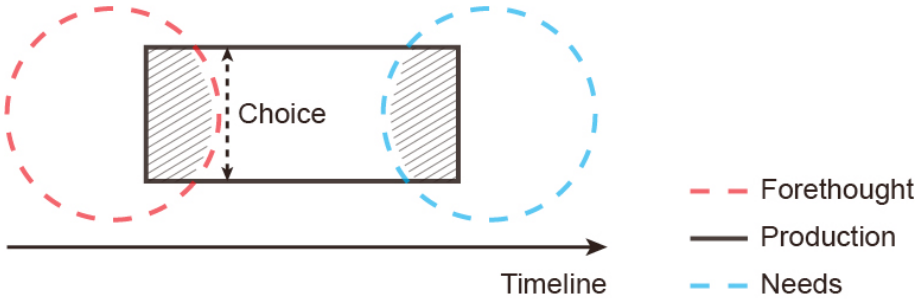

Figure 5. Model during the 3rd industrial revolution

Honeywell T86 circular thermostat is a typical example which combines product function with user experience. The designer Dreyfuss focused on ergonomics, and his design used a unique circular appearance rather than a conventional rectangular one. The overall shape has no redundant keys, and is similar to the appearance of the dial, which facilitates consumers to be familiar with the use mechanism. T86 thermostat reflects the design at that time not only to meet the realization of basic functions, but also pay attention to better user experience.

Figure 6. Honeywell T86. Source: Google

2.4 The summary of previous three industrial revolutions

During the previous three industrial revolutions, design has played a role of forethinking final needs in most cases and conceive products and their plans for manufacture as well as strategies for marketing competition. However, there is a time lag between designers' forethoughts and their final deliveries to the market. Overall, after each industrial revolution, the manufacture efficiency was greatly improved. The time lag in the industrial chain was shortened, and the choices provided by design and manufacture were increased, as shown in Figure 7.

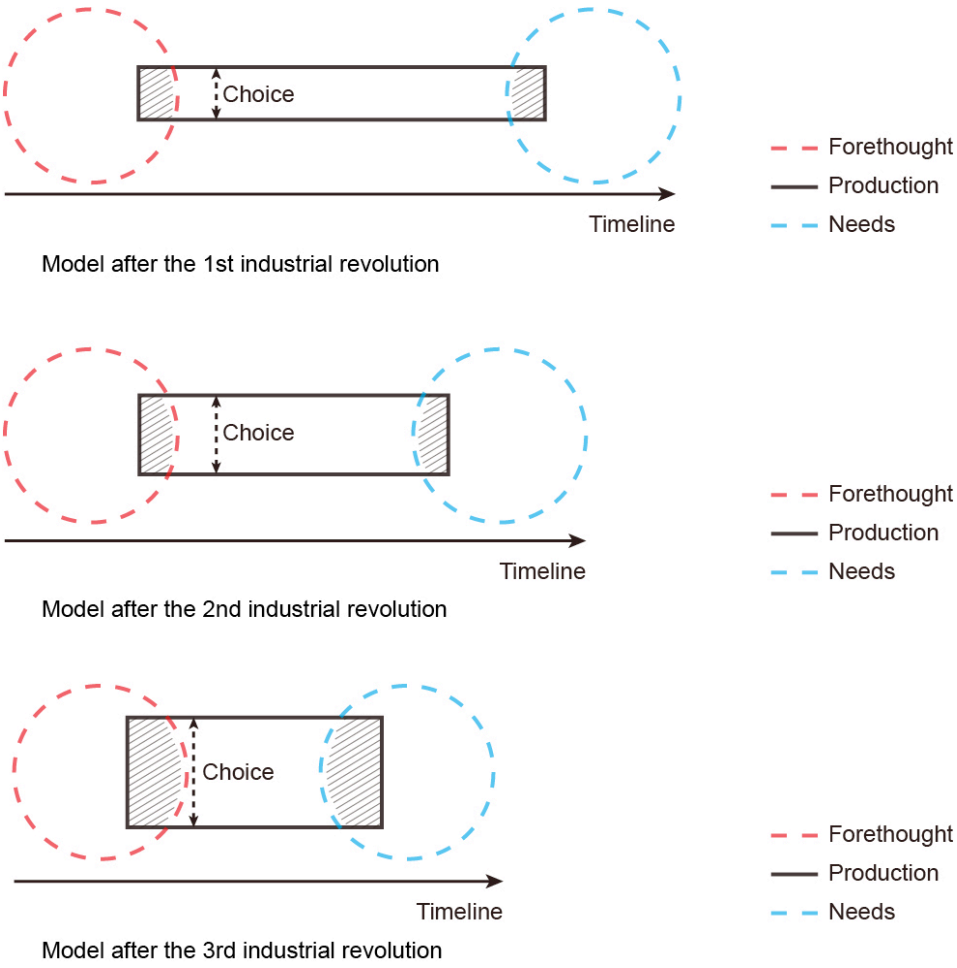

Figure 7. Evolution of three industrial revolutions

From such perspective, design is located at the front-end of the whole industrial chain with a linear model at its nature. The reason behind such model was that a centralized paradigm of manufacture was necessary to provide more efficient production and logistic, as well as more competitive cost due to the available technological environment. But why do we want our industry to be more efficient at the first place? The answer lies at the gap and uncertainty between what the market might want and what we should produce. In Figure 7, the shaded parts represent the user's needs that were satisfied through proper forethought and production. The blank area in the left circle represents the forethought that cannot be fulfilled by production or the inaccurate prediction. The blank area in the left one represents the needs that are not met. The degree of the satisfaction of user needs may be understood as being increasing while the shaded part gets bigger. To conclude, during the last three industrial revolutions, the key of industrial development was to increase efficiency throughout the industrial chain within a linear paradigm, and design has been located at front-end of such chain and playing a role of fore-thinker to help with conceiving and creating the plans for what to manufacture, and predicting what might be popular.

3 The Problem that the previous three industrial revolutions tended to solve

3.1 The knowledge of needs and production

The fundamental problem that our industry and economy have always been longing to solve is the disconnection between the incondensable knowledge of needs and the concentrated

knowledge of production. The knowledge of needs never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess (Hayek. F. 1945). The external performance of the discrete knowledge may be the costumer's pursuit of product diversity. Demand for variety may arise from a taste for diversity in individual consumption and/or from diversity in tastes even when each consumer chooses a single variant (Kevin Lancaster, 1990). The knowledge is constantly changing and unpredictable and users' pursuit of product variety is also hard to measure.

On contrast, the knowledge of production is concentrated in the individuals and organizations that control the means of production. In such situation, though the knowledge of needs is not capturable, our industry still tried its best to produce and sale what might be needed by consulting individuals or organizations whose work involved forethought in the conception and planning of the humanmade world (Richard Buchanan, 2009) to “make sure” the mass-manufactured products will realize their economic and social values. However, such kind of forethought has its limitation of resilience in front of the unpredictable changing personal needs and severe global competition. As long as the fundamental problem exists, the failure of forethought and its consequent unsustainable environmental impact will also co-exist.

3.2 The strategy that industrial development adopted

Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the dynamic and constant change of the market, which represents the individual and collective needs. In order to remedy the fundamental problem, the existing model of our industry tries to improve production efficiency and velocity through technology upgrading. In this way, the time lag between forethought and market is constantly shortened. Such strategy can indeed satisfy needs to a certain extent through offering more choices to more potential customers in less time. But it inevitably comes with the result that products will be produced more efficiently and to be sold and replaced more quickly. The root of such problem lies at the heart of the linear production models in which the communities representing the knowledge of needs in most of the time are excluded as feedback givers. In such context, design plays the role as fore-thinker to explore and conceive possible needs of individuals before manufacture. As the result of technology constraints, the existing linear model has its historical necessity and significance. Relied on design to forecast needs of customers, the centralized manufacture mode was the most effective way to tackle dynamic needs. The previous three industrial revolutions have promoted the evolution of society from traditional manual production to advanced automated production. The user's choice has experienced three times of upgrade: from scratch, from less to more, from more to better.

3.3 The consequence of the strategy

Obviously, there does not exist an omnipotent status, so the forethought from design sometimes could deviate from real needs. Together with the time lag between production and market, this deviation could cause improper production and resource waste, which takes responsibility for sustainability crisis. Nowadays, the sustainability crisis brought by the linear model has become more and more evident. Price volatility, increasing material demand, degradation of ecosystems, decreasing lifetime of products, all these problems cause attention on paradigm transformation. The fundamental cause of the current crisis in sustainability is the industrialization that followed the industrial revolution and the rapid economic growth it fostered. (Hiroshi. K., Kazuhiko T.,2006) Any system based on continual

extraction and consumption will eventually experience limits to growth. Consequently, there is an urgent need for innovation to meet these challenges, by redesigning our economy to be one that creates rather than extracts value, keeping finite technical resources in flow within the economy and protecting and regenerating biological systems. (Ellen Macarthur Foundation, 2019) With the rise of the 4th industrial revolution, emerging technology such as interconnection, informatization, big data, enable opportunities for paradigm transformation. Existing linear models and corresponding roles of design will also convert. We finally have a chance to set our production model into a web-based system. Which enables the spontaneous interaction between the knowledge of the needs and the knowledge of the production.

4 The emerging 4th industrial revolution

On the basis of an advanced digitalization within factories, the combination of Internet technologies and future-oriented technologies in the field of “smart” objects (machines and products) seems to result in a new fundamental paradigm shift in industrial production (Lasi, H., Fettke, P., Kemper, HG. Feld T., Hoffenmann M. 2014). This is the trend of “4th industrial revolution”. It will exert profound influence on all aspects of the society.

4.1 The changing nature of customer demand

Digital technology, especially the Internet, have ensured customization which was the province of the wealthy historically available to a wider range of customers. Chris Anderson (2006) described the phenomenon in his book *The Long Tail*: an increased shift away from mainstream products and markets at the head of the demand curve, replaced by a gravitation toward multiple ever-expanding niches that constitute the curve’s “long tail”. In addition to the growing interest in customization, consumers are increasingly apt to engage in the creation of the products they buy as well. At base, this phenomenon represents a shift in identity from passive recipient to active participant—a blurring of the line between producer and consumer (Deloitte, 2015).

4.2 The changing nature of products

The drive for customization is prompting some manufacturers to reshape their products as physical platforms. This change is not only merely adding software to physical objects, but also allowing for broad customization, and encouraging third-party partners to strengthen the underlying products with additional value. Another transformation is from product to service. Manufacturing firms not only seek manufacturing technique innovation, but are also beginning to focus on induction and impetus of service (Jay Lee, Hung-An Kao, Shanhu Yang, 2015). When products become "smart", interconnected, and even transformed into services, it is obsolete of the concept of creating value by merely manufacture and selling more products. In the future, value will come from connectivity, data, collaboration, feedback loops and learning.

4.3 The changing economics of production

The profound change in the field of manufacture mode is the application of additive manufacture which benefits from the exponentially developing digital infrastructure. Compared with subtract manufacture, the cost of small batch production with additive manufacture is lower, so additive manufacture is more suitable for customization requirements. Meanwhile, the waste caused by additive manufacture is less, the utilization rate of materials is higher, and it fits the requirements of sustainable development. Another

great impact of exponentially developing digital infrastructure is its ability to break barriers and offer opportunities to newcomers. It's easier than ever to learn a new skill or connect with experts in any field. These benefits, first apparent in the digital world, are now trickling down to real world and are likely to inspire both growth and change.

4.4 The changing economics of the value chain

The boundaries between manufacturers and retailers are becoming increasingly blurred. The softening of this role is meaningful not only for companies longing for changing, but also for any intermediaries holding inventory. Under this circumstance, many hardware start-ups abandon the traditional entity retail channels and directly contact consumers through online platforms.

5 From fore-thinker to facilitator

5.1 The keys of the 4th industrial revolution

The previous industrial revolutions upgraded capacity of interacting with the changing dynamic market through the invention of efficiency driven technology. In the age of the 4th industrial revolution, the fundamental problem between the knowledge of needs and the knowledge of production still exists. The knowledge of needs is still discrete and cannot be precisely predict. The difference between the 4th industrial revolution and the precise three ones will be the strategy to tackle such fundamental problem. The previous linear model provided users with more choices through efficiency-oriented technology upgrades, increasing the variety of products and production speed. The 4th industrial revolution will take a different approach. The arrival of the fourth industrial revolution will not only be demonstrated as the improvement of production efficiency, but also the paradigm transformation of effective production web system. The key is to achieve a problem-oriented, real-time, dynamic capability, which means that the design cannot and should not play the role of a fore-thinker in the front-end of manufacture chain as before.

5.2 From fore-thinker to facilitator

If we to realize the reversal of the economic growth paradigm in the coming 4th industrial revolution, to realize the real transformation of industrial development from "efficiency" to "effectiveness" and to achieve circular and sustainable economic growth, the role of design needs to be changed from the previous "fore-thinker" who planned in advance to the "facilitator" who will help to build a new innovative culture. From the historical perspective, design grows from a trade activity to a segmented profession to a field for technical research and to what now should be recognized as a new liberal art of technological culture (Richard Buchanan, 1992). The fundamental change is that the role of design changes from the front-end of production line to the center of the innovation community, from the planning of products and services to the facilitation and curation of innovation communities. The knowledge of design will no longer belongs to a few groups of people but will be sewed through the creative community network of the entire future industry through design culture, as demonstrated in Figure 8.

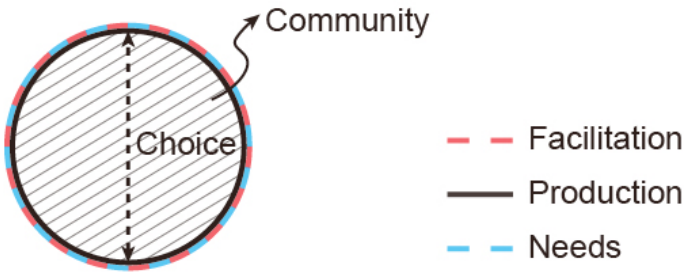

Figure 8. Ideal model for the 4th industrial revolution

In the ideal model, there is no clear front-end and back-end distinction. The parties associated with the product life cycle -- customer, design, manufacture, logistics, etc. -- are closely integrated and exist in the form of an innovation community in which design plays a central role. This user-centred innovation processes offer great advantages over the manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years (Eric von Hippel, 2005). Integration of users in open innovation community can improve the ability of organizations to access external innovation sources and enhance innovation efficiency. In this model, design should open itself to enable the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes (Richard Buchanan, 2006).

5.3 The Emerging Practices

The facilitation of a design culture may not only help to balance the knowledge of needs and the knowledge of production, but also may have a chance to solve the problems left by previous linear model. Nowadays, besides the ecological crisis, there are social crisis, political crisis, cultural crisis, moral crisis, as well as the crisis of democratic ideology and capitalist system (Ernst von Weizsaecker, Ander Wijkman. 2018). Behind the great challenges we face, there is a cultural gap between the artificial world and the ecosphere (John Thackara, 2018). This is closely related to the previous linear development model.

However, there are already emerging practices that have a strong focus of facilitating design culture to tackle global issues by community-based and effectiveness-driven innovation, such as Mozilla for network security; Ellen Macarthur Foundation for circular economy; The Ocean Cleanup for marine ecology; Highline for urban renewal; Nice 2035 for community co-creation. These ongoing projects and practices are not only focusing on design of new products or services, but also on solving complex sociotechnical problems and facilitating a vital, meaning and value creating, and design driven community.

The Ocean Cleanup is non-government engineering environmental organization based in Netherlands, that develops technology to extract plastic pollution from the oceans. The organization use the natural oceanic forces to catch and concentrate the plastic and investigate how to reuse the material. By adopting design thinking and selling branded material for reuse, the organization aims to eventually make the Cleanup self-sustainable. The Ellen MacArthur Foundation is a charity registered in the UK which aims to inspire a generation to re-think, re-design & build a positive future through the framework of a circular

economy. It is committed to building circular economy based on three principles:1 design out waste and pollution. 2 keep products and materials in use. 3 regenerate natural systems. Nice 2035 is a complex space and ecosystem which integrates product research, development laboratory, innovative education space, physical prototype store, multi-creation center, incubator and other functions. Nice 2035 regards community as an important source of innovation in cities, and community residents as an important force of social innovation. It emphasizes the wisdom of ordinary people based on daily life and relies on design colleges' resources and ecology.

The three cases above support our argument that in the forthcoming 4th industrial revolution, design will be involved in a transformation from the "fore-thinker" at the front-end of the original production line to the "facilitator" of design culture widely spread in the future production network. The facilitation of task-driven and community-based design culture might be the key to solve the problems left over from the past industrial revolutions and help us achieve a sustainable development model in the forthcoming 4th Industrial Revolution.

6 Conclusion

This paper puts forward the role that design should play in the coming new industrial revolution and the shift of the focus of research strategies (Buchanan, 2007) that design inquiry and practice should take. The fundamental change the paper tries to promote is that design being at the front of providing ideas for products and services becomes the center of facilitating design cultures for innovation communities.

In order to facilitate such shift, design education institutions and design research communities will continue to pioneer to explore new topics and methods of meaning and vision driven design and innovation research and practice. How can design curate technology cultures to enhance the production and economic adaptability of change? How should design help to connect advanced manufacture and everyday life? How can design and creativity unlock the potential of Industry 4.0 technologies? How we will prepare a new generation of design students who will rise to the challenge of such shift?

7 Reference

Chris Anderson. (2006). The Long Tail: Why the Future of Business Is Selling Less of More. New York: Hyperion.

Deloitte. (2015). The future of manufacturing: making things in a changing world. Retrieved from https://www2.deloitte.com/us/en.html

Donald A. Norman. (2015). DesignX: Complex Sociotechnical System. *She Ji: The Journal of Design, Economics, and Innovation,1*(2), 83-106. doi: 10.1016/j.sheji.2016.01.002

Ellen Macarthur Foundation. (2019) Artificial Intelligence and the Circular Economy: AI as a Tool to Accelerate the transition. Retrieved from https://www.ellenmacarthurfoundation.org/publications

Eric von Hippel. (2005). Democratizing Innovation: The Evolving Phenomenon of User Innovation. *Management Review Quarterly, 55*(1), 63-78. doi: 10.1007/s11301-004-0002-8

Ernst von Weizsaecker, Ander Wijkman. (2018). Come On! Capitalism, Short-termism, Population and the Destruction of the Planet. doi: 10.1007/978-1-4939-7419-1

Hayek, F. (1945). The Use of Knowledge in Society. *The American Economic Review, 35*(4), 519-530. Retrieved from http://www.jstor.org/stable/1809376

Hiroshi Komiyama, Kazuhiko Takeuchi (2006). Sustainability science: building a new discipline. *Sustainable Science, 1*(2), 1-6. doi: 10.1007/s11625-006-0007-4.

History of Ford. (n.d.). Retrieved from https://corporate.ford.com/history.html
Jay Lee, Hung-An, Shanhu Yang. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. Procedia CIRP, 16, 3-8. doi: 10.1016/j.procir.2014.02.001
John Thackara. (2018). How to Thrive in the Next Economy: Designing Tomorrow's World Today. Shanghai: Tongji University Press.
Lasi, H., Fettke, P., Kemper, HG. et al. (2014). Industry 4.0. Business & Information Systems Engineering,6(4), 239-242. doi:10.1007/s12599-014-0334-4
Kelvin Lancaster. (1990). The Economics of Product Variety: A Survey. *Marketing Science, 9*(3), 189-206. doi: 10.1287/mksc.9.3.189
Richard Buchanan. (1992). Wicked Problems in Design thinking. *Design Issues, 8*(2), 5-21. doi: 10.2307/1511637
Richard Buchanan. (2006). Design Research and the New Learning. *Design Issues, 17*(4), 3-23. doi: 10.1162/07479360152681056
Richard Buchanan. (2007). Strategies of Design Research: Productive Science and Rhetorical Inquiry. *Birkhäuser Basel,* 55-66. doi: 10.1007/978-3-7643-8472-2_4
Richard Buchanan. (2009). Thinking about Design: An Historical Perspective, *Philosophy of Technology and Engineering Sciences*, 409-453. doi: 10.1016/B978-0-444-51667-1.50020-3

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